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January 2005 Report of Progress

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1 Jim Alleman **Solid-Phase Thermophilic Aerobic Reactor (STAR) Processing of Fecal, Food, and Plant Residues**

- Final reconstruction of our next-generation STAR reactor was completed in early November 2004, and the reactor was placed shortly thereafter back into operation.
- Commensurate with this restart, we raised our influent solids loading level to 9% total solids, as compared to prior runs at 6% or lower.
- Unfortunately, what we subsequently learned was that our reactor could not handle this high solids loading, or at least could not handle this high loading based on the employed startup procedures. In effect, the biomass in the reactor lost full metabolic capability, such that the reactor had to be shut down in late December.
- The reactor was then cleaned out and is now being restarted at the prior 6% solids concentration.

2 Charles Glass **Nitrogen Cycling in ALS**

- **Zeolite Assessment**

  Experiments with Zeolites were completed in November 2004. The masters student on the project has successfully completed her thesis and defended the work. Zeolites clinoptilolite and chabazite effectively adsorbed ammonia both at low and high concentration 100 – 1000 mg NH_3-N/L. The Langmuir isotherm gave an adequate correlation coefficient compared to the Freundlich isotherm correlation coefficient. The zeolites in this study have the potential to be excellent ion exchangers under peak ammonia concentrations with signature steep breakthrough curves. Of the tested zeolites used in this study, the chabazite ZS500RW/H statistically proved to be the best at adsorbing ammonia under the present conditions. Finally, pretreatment techniques, conducted to improve adsorption capacity, proved to be successful. The most effectual pretreatment process was the one hour heat pretreatment at 600°C. We feel confident that we understand the capabilities of the zeolites selected to adsorb ammonia.

- **Preparation for Year 3**

  As a part of the original proposal and first year of operation, one of the goals of this project was to evaluate the nitrification then denitrification of the condensate water scrubbed from the gas of the STAR system. The original hypothesis was that it was possible to regenerate a zeolite through nitrification of the ammonia adsorbed to the surface. After issues with nitrification in columns during year one occurred, predominantly acclimation and the alkalinity requirements causing a higher ESM than adsorption, in the second year an evaluation of zeolites to remove ammonium from solution was performed and successfully completed.

  This year the PI will investigate the oxidation of ammonium through nitrification in a batch reactor treating the proposed flow rate of the condensate production from the STAR reactor (0.6 L/day) at a concentration up to 1000 mg/L NH_4^+-N. The goals of the project will be to:

1. Establish a culture on a synthetic wastewater, acclimating the biomass to an influent concentration of 1000 mg/L
2. Feed the culture the condensate from the STAR reactor when the shipments are received from Purdue
3. Add chabazite and clinoptilolite to the acclimated biomass to determine if this

enhances the capability of the mixed culture to oxidize ammonium to nitrate

4. Determine the ability to perform nitrification then denitrification in the same system, completing the nitrogen cycle

3 Jeff Volenec **Solids Separation Water Removal from STAR Biosolids Effluent Using Plants**

- **Solid-Phase Thermophilic Aerobic Reactor (STAR) Biosolids Dewatering**

  Due to a lack of STAR effluent availability, aerobically digested corn byproduct will be used as an analog to STAR effluent on upcoming plant dewatering experiments. Food crops (ie. rice, tomato, wheat, and pepper) and non-food crops (ie. dwarf cattail) that are well adapted to environmental stresses, will continue to be evaluated for their effectiveness in dewatering STAR effluent.

- **Physical Plant Growth Medium**

  Inert glass rock is being evaluated as a physical plant growth medium for STAR effluent dewatering. Glass rock was selected due to its non-reactive nature, irregular particle shape and optimal particle size.

4 Jim Alleman **Liquid Freeze-Thaw (LiFT) Urine & RO Brine Processing for Advanced Water Recovery and Salt Separation**

- A decision was made after the EAC meeting to increase the experimental scale of our LiFT study, to that of an approximately 2-3 liter per day operation.
- Construction of this new system continued during December and January, and startup is projected in early February.
- In parallel with this evolution of our technical development, we have also initi ated a complementary modeling effort to further evaluate the theoretical asp ects of tertiary eutectics.

5 Kim Jones **Membrane Processes in ALS**

No report submitted

6 Kathy Banks **Treatment of Grey Water Using Gas Biofilters**

- 6 BREATHe I reactors have been operated to treat graywater simulant since mid November. The effects of two different packing materials, Bee-2000 (Water Management Technologies Inc.) and Biobale (CPR Aquatics). Bee-2000 is shaped like honeycombs and has a surface area of 198 ft^2/ft^3 and Biobale is 1/8" x 2' strands of PVC with a surface area of 250 ft^2/ft^3. Three reactors have been operated with each packing material. It is hypothesized that packing material surface area and geometry will affect reactor performance.
- Monitored parameters during the operation of the BREATHe I reactors include: surfactants (SLES & DSCADA), TOC, total nitrogen, ammonia, nitrate, and nitrite. Reactor operation stabilized after 4 weeks of operation. Surfactant removal has been greater than 95% on average. However, TOC removal is around 60% on average. Reactor operation will be modified to improve TOC removal and the presence of nonbiodegrabable byproducts will be investigated.
- The first generation model developed for the BREATHe system has been built upon. The ability to track changes in pH resulting from chemical and biological transformations has been added to the model. A plan for setup of experiments that will validate the model is currently underway. These experiments will be conducted upon completion of the above discussed experiment.

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7 Al Heber

Gas-Phase Revitalization Using Biofilters in ALS

No report submitted

8 Chip Blatchley

Potable Water Disinfection Subject to Extended Space Travel Constraints

- **Ion Exchange and Ascorbic Acid for Iodine Removal**

  Experimental results suggest that ion exchange and ascorbic acid are effective at removing iodine residuals from water. Ascorbic acid reduces residual (oxidized) iodine species to iodide. Iodide is then adsorbed onto ion exchange resin. Ascorbic acid does not appear to compete with iodide for ion exchange sites.
- ***B. subtilis* Experiments**

  Laboratory equipment was recently purchased for the growth of *B. subtilis* (spores) for dose-response experiments. Experiments with the spores are expected to begin in late February.
- **Investigation of an alternative UV intensity field**

  An alternative UV intensity field model was incorporated into the numerical model that is to be used for evaluating different designs of UV reactor systems for extended space travel. This new model, called the Spherical Source (SS) model, represents a potentially important improvement in the accuracy of representing the intensity field emanating from a UV lamp as compared to the previously used Line Source Integration model. The microbial inactivation results simulated incorporating the new SS model will be compared to inactivation results obtained previously obtained with the LSI model and experimentally measured inactivation.

9 Bruce Applegate
Mike Ladisch

Bioamplification Using Phage Display for the Multiplexed Detection of Pathogens in Potable Water and Food

No report submitted

10 Paul Brown

Waste Treatment Using Tilapia

- **Aquaculture Lab Reconstruction**

The Aquaculture Research Laboratory will be reconstructed this year.

The Dean of the College of Agriculture committed to rebuilding the Aquaculture Research Laboratory the day after an electrical fire completely destroyed the facility in November. We are well on our way toward redesign and reconstruction.

Temporary laboratory space has been identified.

While the lab is being constructed, we will use temporary lab space, owned and managed by Purdue, to continue our research efforts associated with the NSCORT program. We completed our inventory documentation and are in the process of replacing equipment and getting our temporary lab established. We should fully occupy it by the middle of February.

Acquisition of fish has been arranged.

Working with the original supplier of fish, we made arrangements for

acquisition of the same genetic line of tilapia we were working with. Adult fish will be in our temporary lab by the middle of February.

11 Cary Mitchell **Minimizing ESM for ALS Crop Production**

- Hardware tests with plants on the novel LED Intracanopy lighting system continue. Two changes have been made. First, to reduce excessive elongation of young plants and to promote upright growth, plants are thigmo-stimulated for the first 10 days of growth. Second, to maximize light interception, especially at early stages, white poly film walls, floor, and movable false ceiling, were placed closely around the plant-growth area, with the ceiling raised concomitantly with plant growth and increasing illumination. This dramatically reduced the amount of light leakage from the compartment and significantly increased the yield of the third 30-day test crop (harvested 1/7/05). The fourth test is underway with double the plant density, and plant growth currently looks good.
- Strawberry temperature experiments in three reach-in growth chambers are being repeated. The initial experiment was hampered by miscommunication, and strawberry plants were inadvertently maintained without fertilizer water, leading to severe nutrient stress. Plants have been rejuvenated in the greenhouse, and currently a combination of previously stressed and previously unstressed plants of four cultivars (half and half of each cultivar) are being grown in growth chambers under three temperature regimes.
- Experiments with sweetpotato, blueberry, cranberry, and basil are ongoing. Plants in the greenhouse are supplemented to 12-hr days with HPS and MH lights, and growth has been good.

12 Caula Beyl **Solid Waste Processing Using Edible Fungi**

- **Enhancing growth and fruiting of edible fungi on residual plant biomass**

  Continued processing (milling to pass through 2 mm sieve) dried residues of rice, sweet potato, wheat, basil, and tomato for paired ratio tests with legumes (cowpea and soybean) using *Pleurotus spp*, King Stropharia and *Hericium*.

- **Production of Plant Biomass**

  To augment the availability of residual plant biomass for edible fungal growth and biodegradation experiments, crops of soybean, sweet potato, cowpea, tomato, basil, and lettuce were sown in pots containing commercial promix BX in the greenhouse for biomass production. Additional plant material was acquired from Sharon L. Edney of Dynamac Corporation at Kennedy Space Center in Florida

- **Search for resources**

  Explored the literature for instrumentation and other resources that can be used to measure residual lignin and cellulose content in post-autoclaved and post-fungal degraded inedible plant biomass.

13 Lisa Mauer **Novel Storage and Packaging Operations**

Radiation effects on oils and antioxidants project:

- Methods have been optimized for data acquisition and needed equipment has been received.
- Preliminary radiation studies have been conducted to determine sample size, orientation, and dosage needs.
- Consultation with statistical design group will take place this month to make sure needed information can be gathered using a well-designed incomplete factorial approach.

- Radiation treatment, storage, and analysis of primary lipid and antioxidant samples beyond preliminary studies is set to begin in mid-February

Radiation effects on wheat project:

- Working on optimization of techniques for isolation of individual wheat components (proteins, starch, lipids, and antioxidants)
- Preliminary study indicated that radiation has effects on quality and quantity of protein (effects on starch, lipids, and antioxidants will determined)
- Two growth cycles of wheat cultivars have been harvested from the greenhouse, and the third is set to begin in March.

Abstracts submitted to Institute of Food Technologists Annual Meeting:

1. J. Gandolph, J. Burgess, M. Perchonok, B. Watkins, and L.J. **Mauer**. 2005. Effects of gamma-radiation on the reducing power of antioxidants. Institute of Food Technologists' Annual Meeting and Food Expo. July, New Orleans, LA. (submitted)

2. J. Gandolph, J. Burgess, M. Perchonok, B. Watkins, and L.J. **Mauer**. 2005. Effects of gamma-radiation on lipid oxidation and fatty acid composition. Institute of Food Technologists' Annual Meeting and Food Expo. July, New Orleans, LA. (submitted)

3. A. Salameh, L.J. **Mauer**, and L.S. Taylor. 2005. Deliquescence lowering in mixtures of sucrose and citric acid. Institute of Food Technologists' Annual Meeting and Food Expo. July, New Orleans, LA. (submitted)

4. L. Snuffin, M.H. Perchonok, and L.J. **Mauer**. 2005. Food packaging waste scenarios for a mission to Mars. Institute of Food Technologists' Annual Meeting and Food Expo. July, New Orleans, LA. (submitted)

5. A. Stoklosa, D. Nivens, and L.J. **Mauer**. 2005. Characterizing effects of Gamma Radiation on Wheat Proteins and Starches using Atomic Force Microscopy. Institute of Food Technologists' Annual Meeting and Food Expo. July, New Orleans, LA. (submitted)

14 Leonard Williams Optimal Food Safety in ALS

- **Continuing Work on Determination of critical points**
  AAMU Graduate Student has completed preliminary work on determination of critical points on the surfaces of whole tomatoes. The use of pulse light sterilization was a intervention step is currently being investigated.

- **Determination of Biofilms on Surface of Tomatoes**
  Graduate student continue work on biofilm formation on salad crops and microenvironments or 'niches" created by spoilage and pathogenic bacteria. Work is currently examining the "contact strengths and angles" of Salmonella spp. on the surfaces of tomatoes.

- **Combined efficacy of pulsed light and sanitizers**
  Preliminary work to determine combined effects of disinfectants and pulsed light sterilization on inactivation of Salmonella spp. on surface of tomatoes and examines the level of penetration of pulsed light in the tomatoes.

15 J. Pekny, G. Chiu, Y. Yih **Systems Modeling of ALS**

- **Manuscript titled "Effect of Different Waste Recovery Systems on the Overall Waste Generation Rates for Advanced Life Support System" is submitted to special issue of International Journal of Environment and Pollution**

The manuscript named "Effect of Different Waste Recovery Systems on the Overall Waste Generation Rates for Advanced Life Support System" is submitted for a special issue of International Journal of Environment and Pollution this month. This work is an attempt to demonstrate how studies of closed life support systems can be used to advance the understanding of working principles of our biosphere and how this understanding can be used to reduce the pollution and waste generation. Additionally, efficient waste recovery systems that are developed for advanced life support systems (ALSS) to be used in space explorations can be utilized on Earth. As an example of these types of studies, we studied three different ALSS scenarios, each having different waste recovery technologies. The results are compared from a systems point of view to determine the effect of waste recovery systems on the waste generation rates of these systems.

- **Manuscript is in progress for ICES 2005**

In this work, optimum planting area that would minimize the equivalent system mass (ESM) of a bio-regenerative advanced life support system (ALSS) is determined using an advanced crop scheduling module in conjunction with a diet optimization module. A mixed-integer linear programming (MILP) model is developed as the crop scheduling module, whereas a linear programming (LP) model is utilized to determine the diet for the crew-members. Given the activity schedule of the crew members, the diet optimization module is able to calculate the necessary nutritional requirements of the crew members using a dynamic human model. A diet cycle (20-30 days cycle) is constructed that meets these requirements from a list of food recipes (including their nutritional analyses) within a predetermined variety level while minimizing the ESM. Given the demands for each crop for the proposed diet and crop growth parameters for these crops, crop scheduling module determines the best planting schedule that will optimize the system behavior, i.e. the one that would minimize ESM. Due to the uncertainties introduced in the crop growth parameters, different planting schedules are obtained for each run of the crop scheduling module for the same demand levels, which consequently results in different overall planting areas. Once a statistically significant amount of runs are completed, the optimum planting area that would minimize the ESM is determined within a confidence interval.

- **Participated in 90 Day Lunar Transient Modeling Challenge Problem competition**

The findings of the theoretical limit analysis of a single mission versus a re-entrant (multi-cycle mission) lunar base scenario are presented in SIMA telecon on Jan 20, 2005.

17 Julia Hains-Allen **Outreach**

- **Equivalent System Mass Analysis of Plant Growth**

The juniors and seniors from three high schools attending McKenzie Career Center in Indianapolis participated in a semester-long pilot agricultural-

biotechnology-engineering course written by Julia Hains-Allen and Jeff Martin. The course was taught this fall by Jeff Martin, a professional engineer with industry experience. Their mission was to study the "Equivalent System Mass Analysis of Plant Growth" using research grade plant growth chambers designed by Orbital Technologies. On December 7, 2004, the students presented their research findings to a panel of scientists, engineers and educators during a symposium at Purdue. The symposium was organized by ALS/NSCORT. The high school project mirrors NSCORT research but is geared toward getting students interested in pursing careers in science and engineering.

- **Mission To Mars to Continuing Education IVY Tech Directors**

Julia Hains-Allen presented the Mission To Mars 5th-8th grade curriculum model to the continuing education directors from 17 IVY Tech campuses.
Note: Founded in 1963, Indiana Vocational Technical State College (IVY Tech) is a statewide, open-access, community college, providing residents of Indiana with professional, technical, transfer, and lifelong education for successful careers, personal development, and citizenship.
The presentation resulted in a collaborative arrangement between ALS/NSCORT and IVY Tech. ALS/NSCORT will offer a distance learning course "Mission To Mars" for educators in the state of Indiana through IVY Tech continuing education program. Participating educators will receive all the "Mission To Mars" curriculum materials developed by ALS/NSCORT along with continuing education credit. Julia Hains-Allen will lead the instruction. IVY Tech will provide the network for the distance learning program. Two pilot IVY Tech sites will offer the distance learning course in the of Spring 05, followed by a statewide offering through all IVY Tech campuses in the Summer 05 and subsequent years.